JPRS: 4454

13 March 1961

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-USSR-

By V. M. Grigor'yeva

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OFFICE OF TECHNICAL SERVICES
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WASHINGTON 25, D. C.

U. S. JOINT PUBLICATIONS RESEARCH SERVICE
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WASHINGTON 25, D. C.

FOREWORD

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JPRS: 4454

CSO: 1475-S/a

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[Following is the translation of an article by V. M. Grigor'yeva in Gigiyena Truda i Professional'nyye Zabolevaniya (Labor Hygeine and Occupational Diseases), Vol 4, No 10, Moscow, October 1960, pages 35-40.]

Although a great number of unresolved questions still exist, nevertheless a considerable amount of data have been gathered concerning the biological effect of ultrasonic waves on living organisms which have been immersed in water, and on the effect, on both animals and humans, of contact irradiation of the skin surfaces.

The biological effect of ultrasonic waves propagated in the air has far less study. However, it is precisely this information which would be most relevant in judging the possible harmful effects of ultrasonic waves on industrial workers. From a hygienic point of view, the most interesting are the ultrasounds in the air-medium with a frequency of from 16 to 100-150 kilocycles. The conditioning factor here is that within this particular range the absorption of ultrasounds in the air is slight, and closely approximates the absorption of audible sounds. If a sound of 10 kilocycles' frequency is absorbed at the rate of 0.2 decibels per meter, then the absopption of a sound of 100 kilocycles' frequency will be only a little more than 3 db/m. It is only with a further increase in sound frequency, that a sharp increment in its absorption in the air-medium occurs. At a frequency of 500 kilocycles, the absorption will be as much as 40 db/m. In this way, at frequencies of 500-1,000 kilocycles, the distance itself will, in certain measure, serve as a shield against the effects of ultrasounds propagated through the air. Although a definite ultrasonic frequency (most often, 18-20 kilocycles) is used in technological processes, at the same time the air-medium in the work shops contains not just a single frequency, but a complex sonic field consisting of audible and inaudible sounds. In connection with this, hygienists will be interested in the researches mentioned below -- both in the experiments involving ultrasounds of definite frequency, and in those dealing with sounds of complex-spectrum components, in which there is a significant sonic energy in the inaudible frequencies also. The evidence accumulated on this problem shows that ultrasounds, apart from the effects which they have in common with audible sounds, also exert a special effedt. Let us examine the currently available literature, and keep to the following plan: 1) the lethal effect of ultrascunds, 2) effect on the hearing organ, 3) effect on the central nervous system, 4) effect on the blood, 5) effect on the endocrine system.

Lethal Effect

A number of research workers have set up experiments on animals that were subjected to the action of very intense ultrasounds, up to 160-165 db (frequency, 22-22.5 kilocycles). This level they designate as the critical one; the animals die in the course of a few minutes (Allen, Frings, and Rudnick, 1948; Grognot, 1951; Bugard, Souvras, et al., 1953). It was observed that removal of the fur somewhat retards the moment of the animal's death, but even under these conditions, death occurs quite rapidly. Danner, Ackerman, and Frings in 1954, after experimenting with mice in a high-intensity sonic field at different frequencies (6, 12, 18, 22 kilocycles) established that the heating effect increased with the increase in frequency.

When sufficiently strong, sonic fields can be dangerous to human life. In the literature, there is a description of a shocking experiment on 80 volunteers (Spain), who were subjected to the effect of the very intense noise of a jet engine. As a result of this experiment, 28 men died, and in the remaining 52 people who had been subjected to noise of lesser intensity, permanent paralysis developed (Effenberger, 1954). Ultrasonic lethal effect is possible only with very high intensities, and from a practical standpoint, these do not occur in ordinary human activities. However, in exceptional cases, when workers will have to service ultrapowerful ultrasonic emittors in the air-medium, these findings will be a guide in the great danger of powerful ultrasounds. They indicate the necessity of developing a reliable protection during work under these conditions.

Effect on the Hearing Organ

Experiments dealing with the effect of powerful ultrasounds on the hearing organ have not permitted a clear delineation of their specific effedt. Ultrasonic waves induced a mechanical injury of the tympanic membrane, and of the middle ear, just as do powerful audible sounds and powerful aperiodic vibrations produced by different causes, amongst them, a detonation effect (V. F. Undrits and R. A. Zasosov, 1935; K. A. Drennova and A. I. Titov, 1939). The specific effect of ultrasounds on the hearing organ becomes evident when intensities below the injury threshold are used. Experiments conducted by E. P. Ostrovskiy and B. E. Sheyvekhman (1941, 1948) showed that sounds having a frequency of 19,000 cps /cycles per second/ and lower, induce a fatiguing effect (a rise in the threshold of hearing receptivity), while sounds with a frequency of 21,400 cps and higher have a sensitizing effect on hearing (lowered threshold of hearing receptivity). In the frequency interval between 19,000 cps to 21,400 cps, there lies an intermediate area in which there are some cases of fatigue, and some of sensitizing.

With contact ultrasonic irradiation of the hearing organ, done by

Angeluscheff in 1955, fibrose changes were obtained in the inner ear, especially in the region of the oval window. This specific reaction of the hearing organ in response to ultrasonic action permitted the author to express the possibility that otosclerosis is a noise-engendered disease. Initial symptoms of incipient ossification processes in the labyrinth were also indicated with the action on the ear of frequencies in the upper audible range (V. G. Ermolaev, 1936). However, this reaction occurs with greater intensity during the action of high ultrasonic frequencies. Further experimentation with this problem is imperative. During ultrasonic action on the hearing organ, aside from its intensity and frequency, a certain role is also played by the duration of the action, and the method of exposure to sound (propagation in liquid or through the air). At present, we are unable to evaluate the role of each of these factors.

In the literature, there is no description of the results of prolonged, pure ultrasonic action on the human hearing organ under industrial conditions. Tupin (1955) described changes in acoustical sensitivity in those people who, during the course of their work, are exposed to a mixture of audible and ultrasonic action. Although the number of his observed subjects was not great (a total of six people, four of whom were subsequently re-examined), nevertheless, he noted definite hearing changes which differed from those changes observed during the action of ordinary industrial noises. During the first re-examination, all subjects showed a sharpening of hearing acuity at high frequency, while at low frequencies, hearing acuity was either unchanged or lowered. In one examined subject /female/, a sharpening of other sensory perceptions was noted (taste, sight, smell). In subsequent examinations, conducted after one or two years, the character of the hearing change had altered; there was a sharpening of hearing acuity to low frequencies, while at high frequencies, the sharpened acuity had been replaced by dulled hearing perception.

Action of the Central Nervous System

Regarding general reactions in response to ultrasonic action, the information is even more meagre. Allen, Frings, and Rudnick (1948), while experimenting with animals that they exposed to ultrasonic frequencies of 20 kilocycles and 160-165 db intensity, noted an unusual fatigue in themselves toward the end of the experiment. This feeling of great fatigue was observed by a number of research workers while they were exposed to the mixed action of sounds and ultrasounds which occur in testing reactor motors. (Bugard, 1958; Boudreau and Lesage, 1953). Effenberger (1954) describes a sensation of fear and a fainting condition in people placed at a distance of 250 meters from a functioning reactor motor.

Bugard (1958) investigated the electroencephalograms of animals subjected to ultrasonic action of 25 kilocycles' frequency, and 130 db intensity during a fix hours' exposure. Four hours after the end of the experiment, a slowing down of the rhythm and an increase in amplitude was noted on the encephalogram. A very prolonged ultrasonic action increases the change in the curve, while at the same time, occasional increases of great amplitude occur. No direct relationship was observed between the duration of ultrasonic action, and the character of the electroencephalogram. Under the same conditions of ultrasonic irradiation, the animal's electrocardiogram showed a quickening of cardiac rhythm.

In these works, the mechanism of ultrasonic action on the central nervous system is not clarified. However, certain research workers claim that in humans, the action of ultrasounds of insignificant intensity is manifested only through the hearing organs. Thus, K. Kh. Kekcheev and E. P. Ostrovskiy (1941), observing an increase in achromatic visual sensitivity in humans subjected to ultrasonic action, noted a weakening or a disappearance of visual changes when the subjects' ears were stopped up with cotton.

Action in the Blood

In some experiments, distinct changes in the blood and in the neuroendocrine system were noted during ultrasonic action, propagated in the air-medium. Grognot (1953) conducted experiments on humans who were subjected to ultrasonic irradiation of 25 kilocycle frequency. After the head region had been ultrasonically irradiated for an hour with 115 db intensity, an increase in the eosinophile count (from 30% to 50% increase) occurred in 85% of the cases. This increment continued during the course of an hour after the experiment, and was accompanied by a decrease in arterial pressure of 15 mm of the mercury column. Focused irradiation of the hands or other body regions produced an opposite reaction in the blood: the eosinophile count decreased by as much as 30%- 40%. Simultaneous irradiation of the head and hands produced an insignificant eosinophilic increase (up to 10%). With intensities lower than 95 db, no changes in the blood were observed, although the experiment was prolonged to two hours. It must be noted, that during the experiment, the subjects' ears were protected with wax plugs; in this way, the ultrasounds reaching the hearing organ were 30-40 db lower in intensity. The protection of the hearing organ to a definite degree, as well as the discrepant types of blood reaction induced during [ultrasonic] irradiation of various body regions, point to the possibility that ultrasonic action occurs through the body surfaces even with relatively low intensities, starting with 95 db.

Ultrasonic irradiation of deaf-mutes (13 people) did not induce any change in the number of circulating eosinophiles. Moreover, low frequency irradiation of people with a 25%-30% hearing loss, and high frequency irradiation of people with total hearing loss, induced no observable change in the eosinophile number. At low frequencies, people with total hearing loss, and at high frequencies, people with a 30%-40% hearing loss, showed a sharp increase in eosinophile numbers.

With the use of a helmet with absorbed 40 db of ultrasound, and which protected the ears, it was found that people previously having eosinophilia, showed no increase in the eosinophile count after an hour's exposure under these conditions. Data obtained by Grognot with different variants of the experiments, are very interesting; however, the results of the separate experiments contradict each other. On the one hand, experiments on people with either total or partial hearing loss, prove that ultrasonic action on the blood is possible only through the hearing organ, and specifically, through that part which receives high audible frequencies. On the other hand, the experiments in irradiating different body regions, and the helmet experiment show that ultrasonic action also occurs through the skin surface. Although the author /Grognot/ does note the possibility of ultrasonic action in these two ways, he gives no explanation of the contradiction in his obtained results.

Bugard (1958) has described blood changes in rabbits and dogs exposed to ultrasounds of 20 kilocycle frequency, intensity of 150 db, for a period of one to four minutes; another ultrasonic exposure was 120-130 db intensity, and duration of exposure was equal to several hours; and finally, an exposure to the noise of steam and reactor motors, 130 db in intensity, and one to six hours' duration. In the white blood cells, leucocytosis, polynuclearosis, and neutrophilosis resulted. As concerns the eosinophiles in those dogs and rabbits exposed to short term (up to one hour) ultrasonic action, a sharp increase, eight to ten fold, was noted. After a more prolonged ultrasonic irradiation (a duration of two, four, or six hours) the reverse was true, and eosinophilia developed. During this double-phased reaction, the lymphocyte number also decreased rapidly. It must be noted that in this experiment, intense audible sounds did not induce such changes.

Bugard (1953) and others have described the reaction of hemoglobin in animals subjected to the action of ultrasound and mixed noises. If the action of mixed noises did not induce changes in the hemoglobin, then ultrasonic action led to the development of a mild and transient amenia. No changes were apparent in the ROE /?/.

Action on the Endocrine System

Aside from blood reactions, a whole series of changes in the endocrine system of the animals was noted during a single ultrasonic exposure. Such changes also developed in equal measure as a result of the action of mixed sounds. These changes were sufficiently marked, but stayed within physiological limits. With the action of intense sounds and low frequency ultrasounds, there is a characteristic triad result: increase of cellular proliferation in the anterior portion of the hypophysis, in the throid gland, and in the adrenals. After prolonged noise action on the animals (40 hours a week for two months), it was established that the animals were deaf in the absence of hyperfunction of the endocrine system. The latter points to the protective role of deafness in preserving the general well-being of the organism.

The experiments with the action of ultrasonic waves, propagated through the air, on humans and animals, serve to orient, in certain measure, toward the possibly harmful ultrasonic effects on those people who service ultrasonic installations. Final evaluation of such action will obtain after further experimentation under conditions approaching those found in industry.

and also by means of special hygienic and physiological research under industrial conditions. The work of Z. S. Lisichkina is the first research done from this aspect (1958, 1959). Although this research is not yet concluded, the data observed are interesting, merit attention, and can serve as a point of departure in setting up comparable research. In all, she has examined 20 people who have, variously, worked at ultrasonic installations between one and three years. Each subject was observed for seven to ten days. Among those observed, 49.4% of the cases had a lowered pulse rate at the end of the day, after work on powerful ultrasonic installations, while in the control group, the pulse rate fundamentally increased. In 40% of the cases, a rise of 0.5° and more in body temperature occured; in several cases, the body temperature rise was greater that 1°. Skin temperature was elevated in 76.2% of the cases, but basically, not more that 2°. In the blood, a time increase in albumin coagulation was noted, and in 30% of the cases, eosinophilia was observed. In determining the speed of sensomotor reactions, it was noted that the latent period in reaction to light and sound was shorter than in the control group.

It follows from the examples given from the literature, that in most of the experiments, the effect of a powerful ultrasonic field (160-165 db) on animals was studied. Although in the study of lethal effects of highly powerful ultrasounds on animals, the various authors agreed on the critical ultrasonic level, and on the mechanism of lethality, yet in the study of powerful ultrasonic effects on the hearing organ, the experimental results are still highly contradictory.

Thus, in the research done by K. A. Drennova and A. I. Titova (1939), ultrasonic action produced a stronger destructive effect on the hearing organ of rodents. At the same time, it follows from the experimental conditions which were set up, that as a result of propagation through a liquid medium, the most intensive ultrasonic action was on fish.

The effect on the organism of medium and low intensity ultrasonic waves has been studied far less than the action of powerful ultrasounds. Z. S. Lisichkina's research is the only physiological observation known to us to be conducted at the place of work on people who service ultrasonic installations. However, the physiological methods used in these experiments did not permit of a full description concerning the specificity and mechanism of ultrasonic action on the human organism. In particular, the deductions concerning the hyperthermal effect in humans, induced by ultrasonic noise of the given intensity, give rise to doubt, since the increase in skin temperature, where the transformation of acoustical to heat energy first takes place, is not great.

Research workers are faced by a series of unresolved questions: investigation into the character of ultrasonic fields; determination of permissible limits of their size; study of physiological changes in workers exposed to ultrasonic action; clinical study; and, a search for measures of protection from harmful ultrasonic effects.

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